Extending BPMN 2.0 With the Knowledge Dimension

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Abstract: This paper introduces BPMN4KM, an extension of the most suitable business process modeling formalism BPMN 2.0 for modeling knowledge dimension in Sensitive Business Processes (SBPs). The extension is designed methodically by application of the extension mechanisms of BPMN 2.0. We aim at incorporating relevant issues at the intersection of Knowledge Management (KM) and Business Process Modeling (BPM) in order to enrich the graphical representation of SBPs and improve the localization and identification of crucial knowledge mobilized and created by these processes.

1 INTRODUCTION

Sensitive Business Process (SBP) modeling has become primary concern for any successful organization to improve the management of their individual and collective knowledge. A SBP is characterized by a high number of critical activities with intensive acquisition, sharing, storage and (re)use of very specific knowledge «crucial knowledge», high degree of internal/tacit knowledge created and exchanged among experts (who carry out actions with high levels of expertise, creativity and innovation), diversity of information and knowledge sources, high dynamic conversion of knowledge and high degree of collaboration and interactions (intra/inter-organizational) between a wide range of agents/experts. Moreover, it is typically an unstructured or semi-structured BP, encompasses a highly dynamic complexity.

In order to enrich and improve the SBP modeling, we have proposed, in previous work, a conceptual specification of SBP organized in new multi-perspective meta-model, entitled «BPM4KI: Business Process Meta-Model for Knowledge Identification» (Ben Hassen et al., 2017b; Ben Hassen et al., 2017c). BPM4KI explicitly organizes the key concepts and relationships that characterize a SBP. It integrates all relevant perspectives/ dimensions relating to BPM-KM, i.e. the functional, the organizational, the behavioral, the informational, the intentional and the knowledge perspectives. In this research work, we focus more on the «Knowledge Dimension» which is not yet explicited, fully supported and integrated within BPs models and BPM approaches and formalisms.

However, while importance of knowledge dimension is well recognized, there is no clear theoretical background and successful practical experiments of inclusion and implementation of this dimension in BP/SBP models. In such languages as IDEF0, IDEF3, GRAPES BM in GRADE tool , EPC diagrams in ARIS tool (ARIS Expert Paper, 2007), UML 2.0 Activity Diagram (OMG, 2011) and BPMN 2.0 (OMG, 2013), data, information and material flows are often represented in BP models by the same symbols/artifacts and without any unambiguous definitions of the concepts. At the same time knowledge has poor or no modeling capabilities in these formalisms. On the other hand, knowledge modeling languages (KMDL (Gronau et al., 2005; Arbeitsbericht, 2009), GPO-WM (Heisig, 2006), PROMOTE (Woitsch and Karagiannis, 2005) and NKIP (Netto et al., 2013)) have shortcomings concerning their ability to explicitly and fully include the knowledge dimension within BPs models as well as relevant issues at the intersection of KM and BPM. They have limited process perspective representation, i.e. they do not address process logic to full extent and thus there is no possibility to represent data and information. To address this research gap, we propose to extend one of the best known modeling formalism, the Business Process Modeling Notation (BPMN) (OMG, 2013), with the knowledge dimension in order to explicitly

incorporate all relevant aspects related to KM within BPs models, and on the other hand, to enrich the graphical representation of SBPs and improve the localization and identification of crucial knowledge mobilized and created by these processes. In fact, BPMN 2.0 was selected as the most suitable BPM notations for SBP representation, because addresses the highest representation coverage of the set of BPM4KI concepts and incorporates requirements for SBP modeling better than other formalisms (Ben Hassen et al., 2016a; Ben Hassen et al., 2017a). Nevertheless, the main weaknesses identified in this specification regards the knowledge dimension modeling.

The present work presents BPMN4KM: a BPMN 2.0 extension, including all relevant aspects related to knowledge dimension in SBP modeling. The proposed extension is developed using the extensibility mechanisms of BPMN (OMG, 2013).

The rest of the paper is structured as follows: Section 2 presents BPMN 2.0 and related works relevant to the research problem. Section 3 presents the central concepts that describe the knowledge dimension of SBP modeling. Section 4 presents the proposed approach for extending BPMN 2.0 with the knowledge dimension. Section 5 concludes the paper and underlines some future research topics.

2 BACKGROUND AND RELATED WORK

This section presents background research: section 2.1 describes BPMN as one of the most suitable BPM notations; section 2.2 briefly present related works relevant to the research problem.

2.1 BPMN 2.0

BPMN 2.0.2 stands for Business Process Model and Notation (OMG, 2013). It is a graphical representation for specifying BPs in a BP model, and a standard for BP modeling notations. BPMN is initiated as a standard BPM language for conventional business, B2B and services process modeling. It can be used within many methodologies and for many purposes, from high-level descriptive modeling to detailed modeling intended for process execution providing a standardized bridge for the gap between BP design and its implementation. BPMN considers notational elements grouped in five basic categories (Flow Objects, Data, Connecting Objects, Swimlanes and Artifacts). Besides, it has the capabilities of handling B2B BP concepts, such as public, private, collaboration processes and choreographies, as well as advanced modeling concepts, such as exception handling and transaction compensation in addition to the traditional BP.

Several surveys have evaluated the adequacy of BPMN for BPM. From our point of view, BPMN has six main advantages (Ben Hassen et al., 2017):

- It is the BPM standard backed up by OMG, which is based upon a meta-model (OMG, 2013) built with UML, the notation which is the de facto standard for modeling software engineering artifacts (OMG, 2007).
- It is very simple, easy to use, readily understandable and accessible by all business stakeholders.
- BPMN is one of the most recent and expressive BPM notations, grounded on the experience of earlier BPM formalisms, which ontologically makes it one of the most complete BPM formalisms (Recker et al., 2009).
- It is appropriate for modeling collaborative BPs actors that display complex flows with high degree of interactions among process' actors and high degree of information exchanged, developed and shared among participants.
- It is currently the BP notation most used among process modeling practitioners, with more BPM tools support available.
- BPMN is extensible. BPMN 2.0 defines an extensibility mechanism for both process model extensions and graphical extensions.
- Finally, BPMN 2.0 presents the broadest coverage of the set of BPM4KI meta-model concepts (except the knowledge dimension) (Ben Hassen et al., 2017a).

Based in the previous assessments, BPMN 2.0 is taken as a basis for the representation of SBP models.

2.2 BPMN 2.0 Shortcomings

BPMN stresses the process view representation, offering a number of symbols for modeling various decision points, process, activity and event types. BPMN constructs emphasize mainly the support of the control-flow and data perspective when expressing processes' orchestration and collaboration. As other BPM formalisms, BPMN constructs have a shallow coverage of informational, organizational and intentional aspects of BPM. Moreover, BPMN focuses entirely on the functional and behavioral aspects of the BP model.

Nevertheless, the main weaknesses identified in this specification regards the knowledge dimension modeling which represents the core and relevant dimension in SBP models (exploring the collaboration and interaction aspects). Currently, from the point of view of various ways how knowledge (including data and information) are used in organizations, the following issues are not yet fully supported in BPMN 2.0 (neither in any of the above-mentioned BPM and knowledge modeling formalisms):

- Opportunity to clearly distinguish between data, information and knowledge in the representation of flows between SBP activities. The information and data exchange constitutes the basis for knowledge dissemination and generation. Note that, BPMN provides opportunity to model only information and data flow using the same symbols/artifacts and without any unambiguous definitions of the concepts.
- Opportunity to identify the different owners/ sources of knowledge involved in the BP activities and location where knowledge can be obtained and can be clearly stated.
- Opportunity to consider the roles of humans in BP activities, be it as humans (single persons), teams, or communities of practice who bears the internal/tacit knowledge.
- Opportunity to integrate and separate the different types /kinds of knowledge (tacit/explicit dimension, internal/external dimension, factual/procedural dimension, individual/collective dimension, etc.).
- Opportunity to integrate and separate the different nature of knowledge (like experience, basic knowledge, scientific/ technical knowledge, general knowledge, etc.).
- Possibility to illustrate knowledge flows between sources and among activities.
- Possibility to represent the dynamic of acquisition, preservation, transfer, sharing, development, and (re) use of individual and organizational knowledge within and between BPs activities.
- Ability to specify more than two opportunities of knowledge conversions (between knowledge types) taking place in single SBP activity.
- Opportunity to enable modeling the critical/knowledge intensity dimensions of organizational activities which are important to determine the crucial knowledge mobilized and created by these activities.
- Opportunity to accurately represent collaborative aspects and specify how do interactions occur (information and knowledge exchange) in SBPs. These aspects are useful to characterize the SBPs, due to, for instance, the high degree of knowledge exchanged and developed and shared among agents through intra/inter-organizational collaboration, and its dynamic nature. In fact, BPMN 2.0 provides a specific choreography model which allows to concentrate only on conversation between performers. However, this model does not show how performer's knowledge changes during the conversation and communication.

To sum up, BPMN 2.0 diagrams are not adequate for the new SBP modeling requirements. So, to overcoming the discussed shortcomings, BPMN 2.0 will be adapted and extended to be convenient for a rich and expressive representation of SBPs, including all or at least most of the relevant issues at the intersection of KM and BPM.

2.3 Related Work

The integration of KM into BPs has rapidly become the most promising practical and theoretical task in KM. In this context, there have been several attempts to integrate the knowledge concept/dimension in BP models as well as in BPM and knowledge modeling formalisms, e.g, (Gronau et al., 2005; Woitsch et al.,2005; Weidong et al., 2008; Supulniece et al., 2010; Businska et al., 2011; Sulanow et al., 2012; Liu et al., 2012; Ammann et al., 2010; Ammann et al., 2011; Ammann et al., 2012; Netto et al., 2013; França et al., 2015; Gronau et al., 2016).

However, none of the proposed knowledge oriented BPM approaches and formalisms adequately and fully support and represent all relevant aspects of knowledge dimension within BPs models (e.g., differentiation between tacit and explicit knowledge, the different types of knowledge conversion, the dynamic aspects of knowledge, the different sources of knowledge, etc.). At the same time, BPM is challenging - these notations are weak in representing logic/ control flow of the BP and the process perspectives as a whole (i.e., the structural, behavioral, organizational and informational dimensions).

Besides, while importance of knowledge dimension is well recognized, there is no clear theoretical background and successful practical experiments of inclusion of this dimension in the well-known BPM standard. In particular, there are only a few initiatives in the BPM-KM area, which use the BPMN as core formalism and systematically

enhance its capabilities and extend it by KM specific aspects (Ammann et al. 2008, Ammann et al. 2012; Ben Hassen et al., 2016). Ammann et al. (2008) defined an extension of BPMN 1.1 (OMG, 2008) for knowledge-related BPM, called BPMN-KEC (KEC stands for knowledge, employees, and communities). In this work different objects were used: objects for knowledge and information, for knowledge conversions, for associations and for persons. Nevertheless, the proposal has not the necessary expressivity and features to represent the relevant SBP elements, including the knowledge aspect. Another work by Supulniece et al. (2010), proposed an extension of BPMN which roots in concepts implemented in knowledge-oriented modeling language (KMDL) (such as an information object, knowledge object, type of knowledge conversion) (Gronau et al., 2005) with few additions and changes in graphical representation. However, experiments with the integrated notation revealed that the relationship between the phenomena behind the symbols is somewhat unclear in the BPM. Moreover, the relevant aspects of knowledge dimension do not fully supported and represented (like the different types of knowledge mobilized and created by each BP activity, the knowledge flow, the different sources/supports of knowledge, etc.).

To date, to the best of our knowledge, there is a lack of works providing systematic approaches for the development of extensions to the BPMN 2.0 meta-model to consider the knowledge aspect in BPM. However, there are previous works providing approaches to extend BPMN 2.0 (OMG, 2011) to represent their domain specific requirements. Some interesting extension proposals are presented in (Charfi et al., 2011; Stroppi et al., 2011; Baumgrass et al., 2014; Martinho et al., 2015; Jankovic et al., 2015 Braun et al., 2015). The differences between the different research works unveil the need for a unified method for the conceptual modeling of extensions and their representation in terms of the BPMN extension mechanism.

In this paper, we aim to solve the discussed shortcomings and address the gap between BPM and KM. Precisely, this research work presents a rigorous scientific approach to extend BPMN 2.0 for KM. This extension must consider and incorporate all relevant aspects of SBP modeling, including the knowledge dimension, in order to allow a rich and expressive representation of SBPs and improve the localization and identification of crucial knowledge mobilized and created by these processes.

3 MODELING SBPs: THE BPM4KI META-MODEL

This section first introduces the notion of SBP and then present an extract of BPM4KI, a BP independent generic meta-model common to current BPM formalisms which ensures the best suitability to model SBP.

3.1 Notion of SBP

According to Ben Hassen et al., (2016b; 2017a), a Sensitive Business Process is a BP which comprises a high number of critical organizational activities (individual/collective) with intensive acquisition, sharing, storage and (re)use of very specific knowledge « crucial knowledge». It mobilizes a large diversity of information and knowledge sources, consigning a great amount of heterogeneous knowledge. Moreover, an SBP requires a high dynamic conversion of knowledge and a high degree of collaboration and interaction (intra/inter-organizational) among participants. Its execution involves many external agents and the assistance of many experts, who apply, create and share a great amount of very important tacit organizational knowledge, in order to achieve collective objectives and create value. In addition, SBP are typically an unstructured or semi-structured organizational actions, requires substantial flexibility, encompassing a highly dynamic complexity. Due to those characteristics, modeling and organizing the knowledge involved in SBP is relatively critical.

3.2 BPM4KI: A BP Meta-Model for Knowledge Identification

In order to enrich and improve the SBP modeling, we proposed a semantically rich conceptualization for specifying a SBP organized in a new generic multi-perspective meta-model of BP representation, the Business Process Meta-Model for Knowledge Identification (BPM4KI). The enriched meta-model serves two purposes: (i) to deepen the elements and dimensions defining a SBP, by offering a coherent conceptual specification for this BP type, and (ii) to develop a rich and expressive graphical representation of SBPs to improve the localization and identification of crucial knowledge mobilized and created by these processes. The current version of BPM4KI offers a referential of generic concepts and relationships relevant to the BPM-KM domain semantically rich and well-based on «core» domain

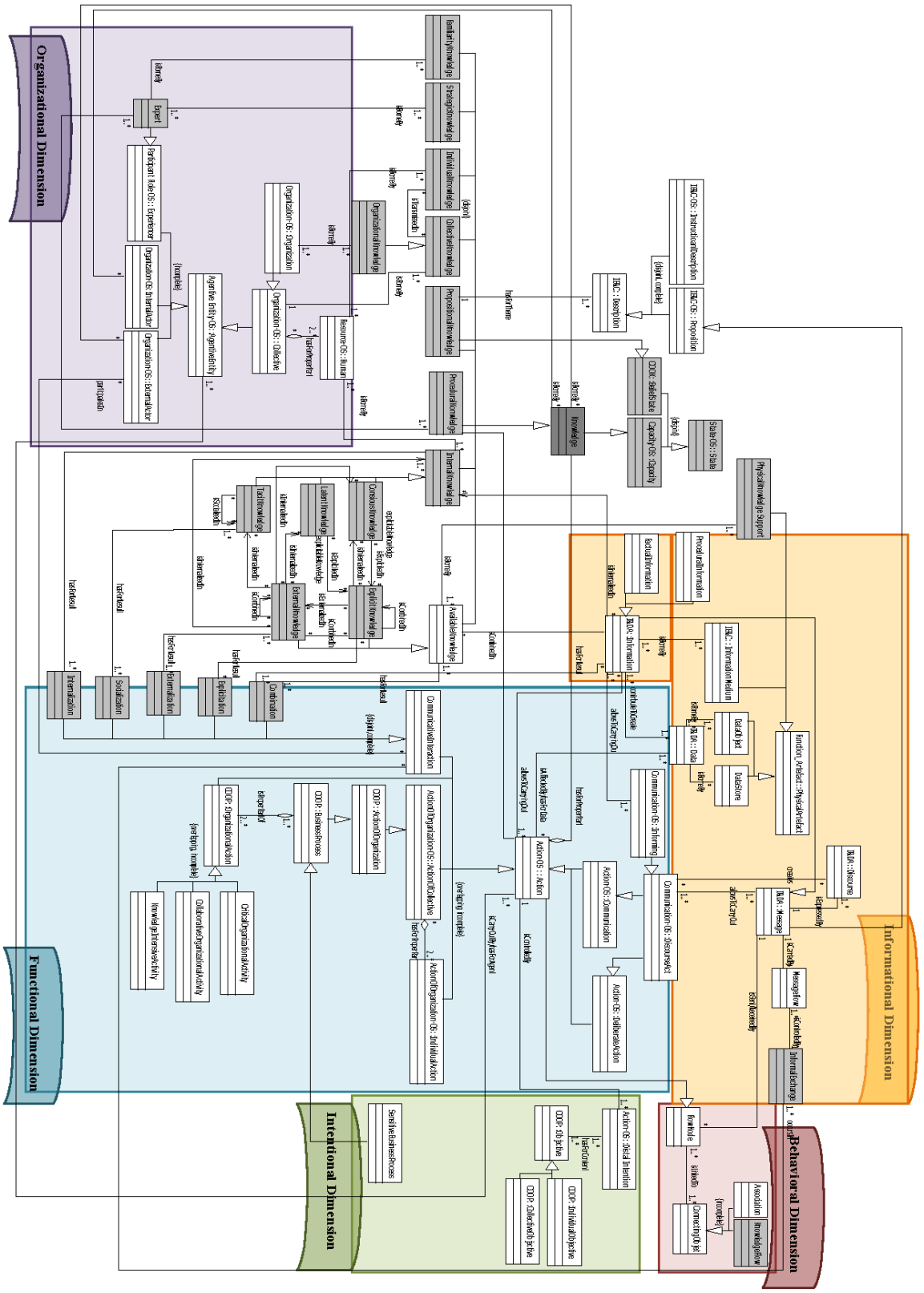

Figure 1: An extract of BPM4KI meta-model: conceptual ontology design pattern relating to the knowledge perspective/dimension of SBP modeling **(**with inter-aspects relationships).

ontologies (Kassel, 2005; Gangemi, 2006; Kassel, 2010; Kassel et l., 2012; Turki et al., 2016), which are based on top of the DOLCE foundational ontology (Masolo et al., 2004). BPM4KI were categorized in six perspectives (or dimensions), namely, the functional, the organizational, the behavioral, the informational, the intentional and the knowledge perspectives. The different dimensions are crucial for a complete understanding, characterization and representation of an SBP (Ben Hassen et al., 2016b; 2017b; 2017c).

The different aspects are required to characterize the SBPs, due to the high degree of knowledge exchanged and developed and shared among agents through intra/inter-organizational collaboration and to the frequent process evolution along time. We point out that the knowledge dimension (supporting the new SBP modeling requirements) is not yet, however, not yet explicited, fully supported and integrated within BPs models and BPM formalisms (Ben Hassen et al., 2016b; 2017c). So, we aim at obtaining new knowledge helpful for developing BPM formalisms that could adequately support above-mentioned issues in BP/SBP modeling.

The «Knowledge Perspective» is modeled as an Ontological Design Patterns (ODP) (Gangemi et al., 2006) represented as a UML class diagram. The Knowledge ODP is based on the reuse and the specification of central generic concepts (and the relationships between them) defined in different ontological modules of the global and consistent ontology OntoSpec (Kassel, 2005; 2010): *Action-OS*, *Action of Organization-OS*, *COOP*, *Partcipation-role-OS*, *Agentive Entity-OS*, *Organization-OS*, *Function & Artefact-OS*, *Capacity-OS*, *Artefact-OS*, *Resource-OS*, *Communication-OS*, *I&DA-OS (Information and Discourse Acts)*, *IE&C-OS (Inscription, Expression and Conceptualization)* and *Action Model-OS*. These ontological modules are available online (http://home.mis.u-picardie.fr/~site-ic/site/spip.php?article53), which are sufficient, on the one hand, to broaden and deepen the knowledge dimension elements, and on the other hand, to characterize the useful concepts for a rigorous specification and an enriched modeling of SBPs. Figure 1 organizes and explicit the central concepts of the knowledge perspective of BPM4KI (marked in gray), in addition to inter-aspects relationships, giving a view of all relevant aspects of the BPM4KI meta-model as a whole.

In this research work, we focus more on the description and analysis of the knowledge dimension which represents the most relevant aspects of SBP modeling, exploring the KM aspect, the collaboration and interaction and all relevant SBP elements (such as individual and collective dimension of activities; critical activities mobilizing crucial knowledge; knowledge intensive activities; dynamic aspects; collaboration and interaction among agents contributing to knowledge creation and sharing;

According to Ben Hassen et al. (2016b), a Knowledge is the `Capacity` (or disposition) to perform (and affects) a type of `Action` aiming to achieve an `Objective`. It `isBorneBy` an `Agentive Entity` (as `Human`, `Collective`, `Expert` or `Organization`). There are several typologies of knowledge according to different dimensions (Ben Hassen et al.. 2016b). For example, `Knowledge` is divided into `Internal Knowledge`, `Explicit Knowledge` and `External Knowledge` according to the *source of knowledge* dimension. Besides, `Knowledge` may be either `Propositional Knowledge` or `Procedural Knowledge` according to the *nature of knowledge* dimension; `Strategic Knowledge` and `Familiarity Knowledge` according to the *organizational value of knowledge* dimension. Moreover, knowledge can be divided into `Individual Knowledge` and `Collective Knowledge` according to the *organizational coverage of knowledge* dimension. With respect to the limited space of this paper, a comprehensive description of the different concepts present in this meta-model is detailed in (Ben Hassen et al., 2016 b, Ben Hassen et al., 2017b; Ben Hassen et al., 2017c).

Furthermore, it is important that an appropriate BPM formalism provides explicit representation of the different issues related to the knowledge dimensions in BPM. In this context, the SBPs can be graphically represented, using the well-known standard for BPM, BPMN 2.0 (OMG, 2013), in order to localize and identify the knowledge that is mobilized and created by these processes. However, as BPMN does not support the knowledge concept, we have extended it. The following section explains our extension proposal for including the knowledge dimension in SBP modeling.

4 BPMN4KM: BPMN EXTENSION FOR MODELING THE KNOWLEDGE DIMENSION

At the root of the success of modeling, design, reengineering, and running BPs/SBPs is effective use and support of organizational knowledge. Knowledge must be considered as one of the BP dimensions, because knowledge is related to action, it is implemented in the action, and is essential to its development. Knowledge is used to perform a process, it is created as a result of process execution, and it is distributed among process participants. However, while importance of knowledge dimension is well recognized, there is no clear theoretical background and successful practical experiments of inclusion, support and implementation of this dimension in BP meta-models and BPM approaches/formalisms (Ben Hassen et al., 2017c). In this paper, we aim at obtaining new knowledge helpful for developing BPM formalisms that could handle all relevant aspects related to knowledge dimension (including data and information). Indeed, extending BP models with the knowledge dimension would provide the following benefits (Ben Hassen et al., 2017c):

- Possibility to relate different forms of knowledge, information and data to the BP model.
- Possibility to identify data, information and knowledge inputs and outputs in different types of organizational activities.
- Illustrating and separating the data, information and knowledge sources/owner that are required to perform BP activities and knowledge that are generated, created and/or modified as a results of activities.
- Enhance the localization of knowledge (where knowledge can be obtained and clearly stated), experts who hold the (internal) knowledge) as well as their characterization.
- Integration and distinction of different knowledge types/nature.
- Specifying the different opportunities of knowledge conversion between knowledge types (the dynamic sharing, dissemination, generation and use of existing knowledge).
- Possibility to represent knowledge flows between sources, and among activities which are about creation, organization, distribution and reuse of knowledge among BP participants.
- Giving an opportunity to improve understanding about the knowledge usefulness, validity, and relevance for particular activities (i.e. critical activities) in an SBP.
- Possibility to evaluate the amount of lost knowledge if a person-owner of knowledge-leaves the organization (to identify which tacit knowledge in which cases should be transformed into explicit knowledge).

According to the above-mentioned arguments knowledge and BPs are directly related and their integrated consideration is indispensable. In this section, we propose a BPM technique that supports an integrated consideration of BPs and knowledge. The proposed technique is an extension of BPMN 2.0.2 (OMG, 2013), where the standard notation is supplemented with knowledge modeling related concepts. Despite its expressiveness, BPMN 2.0 does not yet explicitly represent the key concepts of the Knowledge perspective (such as `Individual Tacit Knowledge`, `Collective Tacit Knowledge`, `Expert`, `Explicit Knowledge`, `External Knowledge`, `Socialization`, `Externalization`, `Internalization`, etc.). To overcoming the shortcomings of BPMN 2.0, some of its concepts must be adapted and extended to include all or at least most of the relevant SBP elements. In this context, BPMN 2.0 defines four standard extension mechanisms that are important for extending SBP model with knowledge dimension. We have introduced the main concepts of the knowledge dimension into BPMN with a some additions and changes in graphical representation.

4.1 The BPMN 2.0 Meta-Model

The BPMN formalism definition is based upon a meta-model (OMG, 2013), which describee the notation's abstract syntax (by means of meta-classes, meta-associations and cardinality constraints). The BPMN meta-model includes elements from three diagrams, targeting the following different purposes: (i) for modeling processes' orchestration and collaboration diagrams; (ii) to simplify the perspective of collaboration diagrams through conversation diagrams and (iii) for modeling participant's interactions through the choreography perspective. In this paper, from the full meta-model that includes 151 meta-classes and 200 meta-associations, we only consider the subset of elements concerning the orchestration and collaboration diagrams.

Main Concepts of BPMN 2.0. Meta-Model. The OMG's BPMN meta-model (OMG, 2013) considers the four main dimensions of BPM:

The functional and behavioral dimensions of BPs support the description of BP activities and their synchronization along with events happening during process execution through the notions of `FlowElementContainer` (which can be either a *Process* or a `SubProcess`) is a container of instances of `FlowElement`. A flow element can be either a `FlowNode`, a `SequenceFlow` or a `DataObject`. A `SequenceFlow` is used to show the order of various kinds of `FlowNode` elements and the interactions between the participants. A `SequenceFlow` may refer to an `Expression` that acts as a gating condition. Instances of `SequenceFlow` can link various kinds of `FlowNode` elements. A `FlowNode` can be one of the several different kinds of `Activity`, `Event` or `Gateway`. A `Gateway` is used to control how `SequenceFlow` interact within a process. An `Event` is something that happens during the course of a process. It can correspond to a trigger, which means it reacts to something (`catchEvent`), or it can throw a result (`throwEvent`). An `Event` can be composed of one or more `EventDefinitions`. There are many types of `Event Definitions`: `ConditionalEventDefinition`, `Timer EventDefinition`, etc. An `Activity` is a work performed within a process. An `Activity` can be a `Task` (*i.e.* an atomic activity), a `Sub Process` (*i.e.* a non-atomic activity) or a `CallActivity`. A `Task` is used when the work is elementary (*i.e.* it cannot be more refined). BPMN2.0 identifies different types of tasks: `Service Task`, `User Task`, `Manual Task`, `Send Task` and `Receive Task`. The meta-class `Process` describes a sequence of instances of `Activity` carried out in an organization with some specific objectives. If a process interacts with other processes, it must participate in a `Collaboration`. The collaboration is a way of grouping several participants. Each `Participant` (aka Pool) must address only one process. Given the fact that a `Participant` is also an `InteractionNode`, it can send or receive several instances of `MessageFlow`.

Regarding the organizational dimension of processes, an activity is accomplished by a `ResourceRole`. A `ResourceRole` can refer to a `Resource`. A `Resource` can define a set of parameters called `ResourceParameters`. A `ResourceRole` can be a `Performer`, which can be a `HumanPerformer`, which can be in turn a `PotentialOwner`. Besides, the `LaneSets` (i.e. pools and lanes) allow grouping BPMN 2.0 model elements according to participants of the process, information systems, organization structure, etc.

Regarding the informational dimension of processes, an `ItemAwareElement` references element used to model the items (physical or information items) that are created, manipulated and used during a process execution. The `ItemAwareElement` is an abstract meta-class, from which derives several data related meta-classes representing transient (`DataObject`) or persistent (`DataStore`) data containers, as well as input or output data to/from `Activity` by means of meta-classes derived from `Data Association`. It includes `DataObject`, `Data Object Collection`, `DataObjectReference`, `Property`, `Data Store Artifact`, `Data Input` or `Data Output` (Collection). Moreover, the `Artefacts` (i.e. *Group* and *Annotation*) allow representing process data.

4.2 Mapping BPMN&BPM4KI Meta-Models: Analysis of BPMN Support for the Knowledge Dimension Concepts

As shown in Table 1 BPMN lacks support for several concepts of the knowledge aspect meta-model (the ODP relating to the knowledge perspective of SBP modeling). Therefore, to remedy for this lacks, we define an extension of the BPMN specification, called BPMN4KM, which introduces the knowledge dimension aspects and provides a rich and expressive representation of SBPs to identify and localize the crucial knowledge mobilized by these BPs.

In fact, we argue that an extension should widely make use of standard elements in order to exhaust the vocabulary of BPMN and reduce new elements to a minimum. Based on both the specific SBP domain concepts and requirements, the comparison with standard BPMN is conducted in order to identify a reasonable need for extension. According to the presented knowledge ODP (Section 3.2), each concept is examined regarding its semantically equivalence with standard elements. Therefore, the respective element descriptions, rules and explanations within the BPMN specification (OMG, 2013) were analyzed in-depth. This leads implicitly

Table 1: Analysis of the BPMN support for the knowledge dimension ODP/ meta-model (with relevant inter-aspects relationships) and derivation of concepts for the BPMN meta-model of the extension.

BPM4KI Concepts		Equivalence Check/BPMN Concept	Support Level	Extended BPMN Meta-model
Knowledge Perspective	Knowledge	- (No equivalence)	-	Extension Concept
	Internal Knowledge	-		Extension Concept
	Tacit Knowledge	-	-	Extension Concept
	Latent Knowledge	-	-	Extension Concept
	Conscious Knowledge	-	-	Extension Concept
	Explicit Knowledge	-	-	Extension Concept
	External Knowledge	-	-	Extension Concept
	Procedural Knowledge	-	-	Extension Concept
	Propositional Knowledge	-	-	Extension Concept
	Strategic Knowledge	-	-	Extension Concept
	Familiarity Knowledge	-	-	Extension Concept
	Individual Knowledge	-	-	Extension Concept
	Collective Knowledge	-	-	Extension Concept
	Organizational Knowledge	-	-	Extension Concept
	Physical Knowledge Support	-	-	Extension Concept
Behavioral Perspective	Message Flow	Equivalence → Message Flow	+	BPMN Concept
	Association	Equivalence → Association	+	BPMN Concept
Functional Perspective	Action Of Collective	Conditional equivalence [1]→ Process	+	Extension Concept
	Organizational Activity	Equivalence → Activity, Task, Sub Process	+	BPMN Concept
	Deliberate Action	Conditional equivalence → Activity	Partly	Extension Concept
	Discourse Act	Conditional equivalence → Activity, Task	Partly	Extension Concept
	Critical Organizational Activity	Conditional equivalence → Activity	Partly	Extension Concept
	Collaborative Organizational Activity	Conditional equivalence → Activity, Choreography Activity	Partly	Extension Concept
	Knowledge Intensive Activity	Conditional equivalence → Activity	Partly	Extension Concept
	Communicative Interaction	Conditional equivalence → Activity, Choreography, Collaboration, Conversation	-	Extension Concept
	Socialization	- (No equivalence)	-	Extension Concept
	Internalization	-	-	Extension Concept
	Explicitation	-	-	Extension Concept
	Externalization	-	-	Extension Concept
	Combination	-	-	Extension Concept
Organizational Perspective	Agentive Entity	Conditional equivalence → Resource Role/Performer, Participant (Partner/Role Entity)	Partly	Extension Concept
	Collective	Conditional equivalence → Resource Role/Performer, Participant	Partly	Extension Concept
	Organization	Conditional equivalence → Resource Role	Partly	Extension Concept
	Human	Equivalence → Resource Role, Human Performer	+	BPMN Concept
	Experiencer	Conditional equivalence → Human Performer, Potential Owner	Partly	Extension Concept
	Expert	- (No equivalence)	-	Extension Concept
Information Perspective	Information	- (No equivalence)	-	Extension Concept
	Information Medium		Partly	Extension Concept
	Physical Artefact	Conditional equivalence →Data Object	Partly	Extension Concept
	Data	- (No equivalence)	-	Extension Concept
	Discourse	-	-	Extension Concept
Intentional Perspective	Sensitive Business Process	Conditional equivalence → Process	Partly	Extension Concept
	Distal Intention	- (No equivalence)	-	Extension Concept
	Objective	-	-	Extension Concept

[1] Process only define the Action of Organization (Business Process) which is an Action of Collective performed by a group of individuals affiliated with the organization (Kassel et al., 2012). However, Process cannot be used to specify the actions that can be carried out collectively by the individuals making up the Collective.

to the derivation of the BPMN4KM meta-model and its stereotypes.

According to (Braun et al., 2015), the following rules are defined for the equivalence check

(correspondence between concepts of the knowledge perspective ODP/meta-model (extract of BPM4KI) and the BPMN mata-model):
- ***Equivalence*:** There is a semantically equivalent construct in the BPMN in the sense of a permitted combination of elements or just a single element. In this case, no extension is necessary and the domain concept is represented as BPMN concept.
- ***Conditional equivalence*:** There is no obvious semantic matching with standard elements, but rather situational discussion is necessary in order to provide arguments for a possible mapping or to explain why it is not feasible. This situation is caused by the partial under specification of BPMN elements (OMG, 2013). Consequently, the concept is either treated as equivalent concept or as non-equivalent concept.
- ***No equivalence*:** There is no equivalence to any standard element for three reasons: First, the entire concept is missing. In this case, the domain concept is represented as Extension Concept in the BPMN4KM meta-model. Second, a relation between two concepts is missing. Therefore, an association between the affected concepts is constructed in the BPMN4KM meta-model. Third, properties of a concept are missing. Then, an owned property is assigned to the element in the extended model. Table 1 provides the conducted equivalence check and its implications for the extended BPMN meta-model. As result of the correspondence check, the concepts of the BPMN4KM meta-model are classified/characterized as *BPMN Concepts* (are those that match with some concept of the BPMN meta-model) or as *Extension Concepts* (are those defined in the domain of the extension).

The following section shows the developed BPMN meta-model extension using the BPMN 2.0 extensibility mechanisms.

4.3 The BPMN4KM Meta-Model

The BPMN meta-model (OMG, 2013) can be extended by integrating new domain-specific concepts to standard and predefined BPMN elements. This is supported by a standard extension mechanism consisting of four elements:

- `ExtensionDefinition`- specifies a named group of new attributes, that can be used by standard BPMN elements. Thus, both new concepts and new additional attributes can be defined (jointly added/attached to the original BPMN elements).
- `ExtensionAttributeDefinition`- defines new /particular attributes that can be specified for an `ExtensionDefinition` element.
- `ExtensionAttributeValue` - contains the value assigned to an extension attribute of a BPMN element.
- `Extension`- binds/imports the entire `ExtensionDefinition` element and its attributes to a BPMN model definition in order to make them technically accessible.

Figure 2 presents the Class Diagram of BPMN extension. By associating a BPMN element with an `ExtensionDefinition`, every BPMN element which subclasses the BPMN `BaseElement` can be extended with additional attributes. Therefore, BPMN 2.0 with their different extension mechanisms appear to provide the most complete coverage of the concepts and constructs needed for analyzing and modeling most of the SBP characteristics.

Despite the fact that BPMN offers a well-defined extension interface, only very few BPMN extensions make use of it (Braun et al., 2014), what hampers comprehensibility, comparability between developed extensions and impedes the straightforward integration of extensions in modeling tools. We suppose, that the missing procedure model for extension building in BPMN causes this lack of rigor.

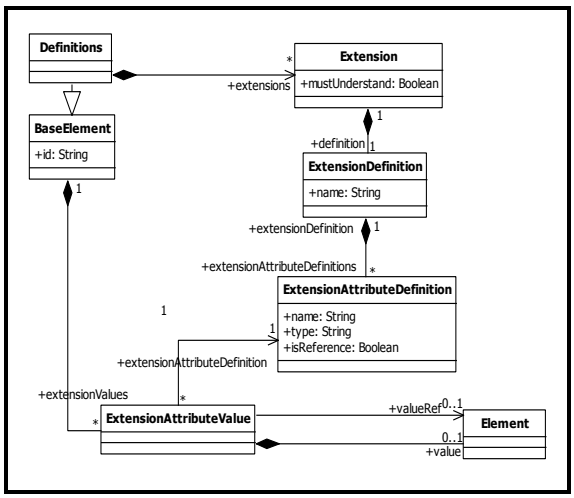

Figure 2: BPMN extension class diagram.

Based on the model transformation rules stated in Stroppi et al. (2011), we define the BPMN4KM extension model (BPMN+X model). Figure 3 below presents the resulting extended BPMN meta-model. In this figure only the relevant standard BPMN classes are shown in white. The BPMN4KM concepts are shown in grey. We associate

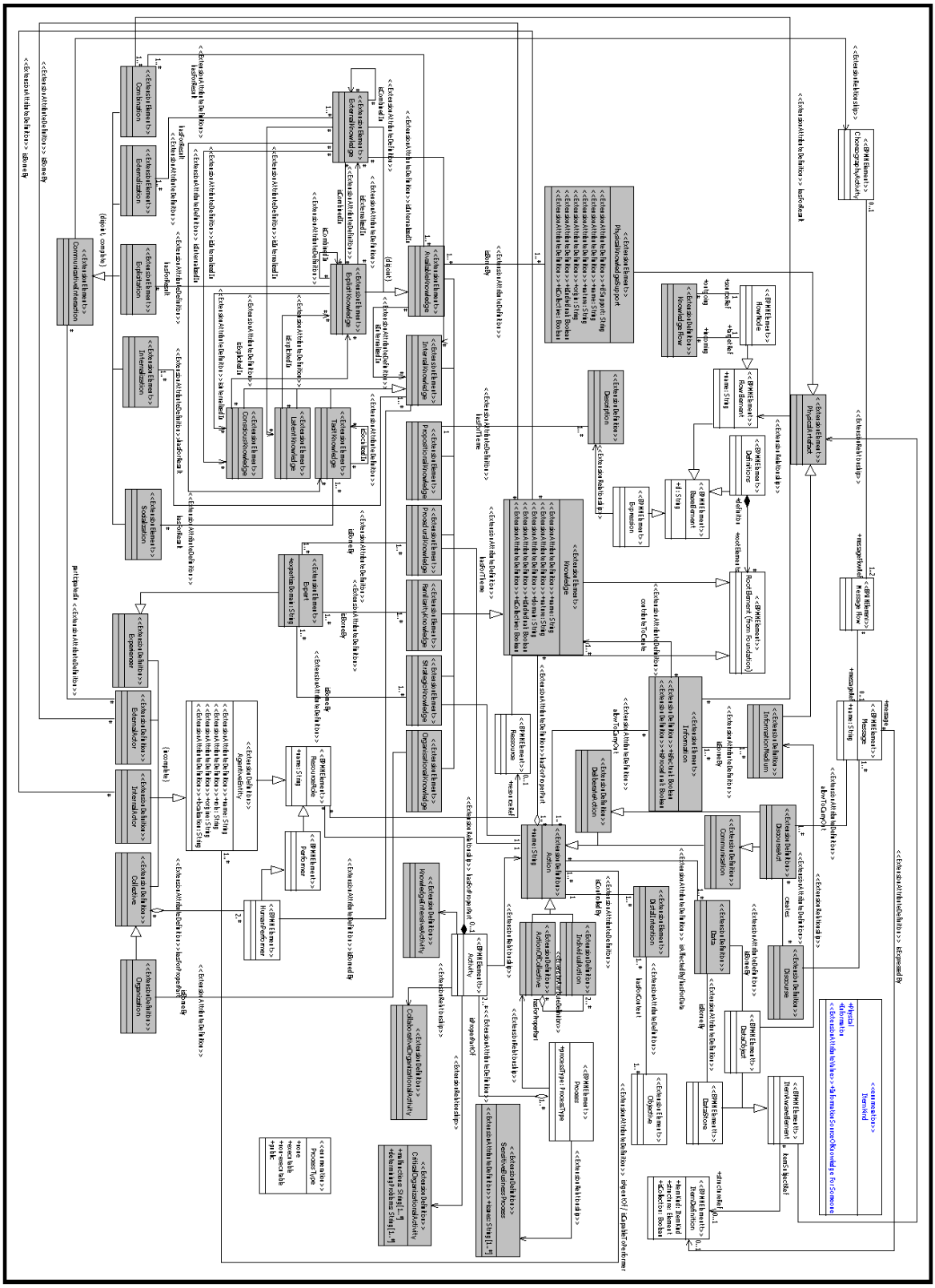

Figure 3: Abstract syntax of the BPMN4KM extension.

`Knowledge` concept with the `RootElement` of the BPMN specification. The semantics and the abstract syntax of the BPMN4KM elements are based on the specification of the BPMN extension mechanism (OMG, 2013). *BPMNElement* allows representing an original element of the BPMN meta-model. *ExtensionElement* allows representing a new element in the extension model which is not defined in the BPMN meta-model (such as `Knowledge`, `InternalKnowledge`, `TacitKnowledge`, `ExplicitKnowledge`, `ProceduralKnowledge`,`ExternalKnowlede`, `PhysicalKnowledgeSupport`, `Information`, `DistalIntention`, `Combination`, `Socialization`, `Internalization`, `Externalization` and `Explicitation`). *ExtensionDefinition* allows specifying a named group of attributes which are jointly added to the original BPMN elements (such as `KnowledgeFlow`, `Experiencer`, `Collective`, `Information Medium`, `KnowledgeIntensiveActivity`, `CriticalOrganizationalActivity`, `CollaborativeOrganizationalActivity`, and `Sensitive Business Process`). *ExtensionDefinition* has the same meaning than the `ExtensionDefinition` element of the BPMN metamodel. The semantics defined by the *ExtensionAttributeDefinition* element of the BPMN meta-model is captured by the *Property* metaclass of the UML metamodel. Thus, *ExtensionAttributeDefinition* is represented in BPMN4KM models by UML properties, either owned by the ExtensionDefinition elements or navigable from them through associations. The properties of *ExtensionDefinition* and *ExtensionElement* elements can be typed as a *BPMNElement*, *ExtensionElement*, *BPMNEnum*, *ExtensionEnum* or UML primitive type.

Finally, *ExtensionRelationship* specifies a conceptual link between a *BPMNElement* and a *ExtensionDefinition* element aimed to extend it. The BPMN extension mechanism cannot express the BPMN element to be extended by an extension definition. Thus, the definition of an *ExtensionRelationship* does not produce any effect in the resulting BPMN extension. *ExtensionRelationship* is provided to help conceptualizing extensions since extensions are generally defined to customize certain elements of the BPMN meta-model.

With respect to the limited space of this paper, the application of each applied transformation rule cannot be presented.

5 CONCLUSION AND FUTURE WORK

This research work presents BPMN4KM: a BPMN extension to explicitly represent, integrate and implement the knowledge dimension in BP/SBP models. It allows a rich and expressive representation of SBPs in order to improve the localization and identification of crucial knowledge mobilized and created by these processes. The proposed approach extension is developed using the extensibility mechanisms of BPMN.

Our current research activities focus on achieving the implementation of the proposed extension according to BPMN4KM meta-model.

As further work, we will validate the BPMN4KM meta-model by instantiating it in depth (using extended BPMN) with real medical care processes in the context of the Association of Protection of the Motor-disabled of Sfax-Tunisia (ASHMS) (Ben Hassen et al., 2017a), in order to verify the completeness of the proposed concepts.

Another issue we will address with BPM4KI and BPMN4KM is to propose a solution to model and specify SBPs integrating relevant aspects related to all BPM4KI dimensions. The general framework we will propose for supporting SBP representation advocates a model driven engineering approach considering at the CIM level, a specific meta-model, the BPM4KI meta-model for modeling SBPs, and at the PIM level, an extension of BPMN (BPMN4SBP meta-model). We aim at automatically generating SBP models to enhance the knowledge identification.

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